CARBON-CARBON RADIATOR

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Carbon-Carbon

- Carbon-Carbon (C-C) - Composite material that uses carbon for both the fiber and the matrix material
  - produced in a high temperature furnace in a lengthy process
- C-C has high thermal conductivity, good strength, and is lighter than Aluminum
- C-C used in high temperature applications
  - Aircraft brakes, Space Shuttle wing leading edge
- Limited applications elsewhere to date, primarily due to cost and production lead time

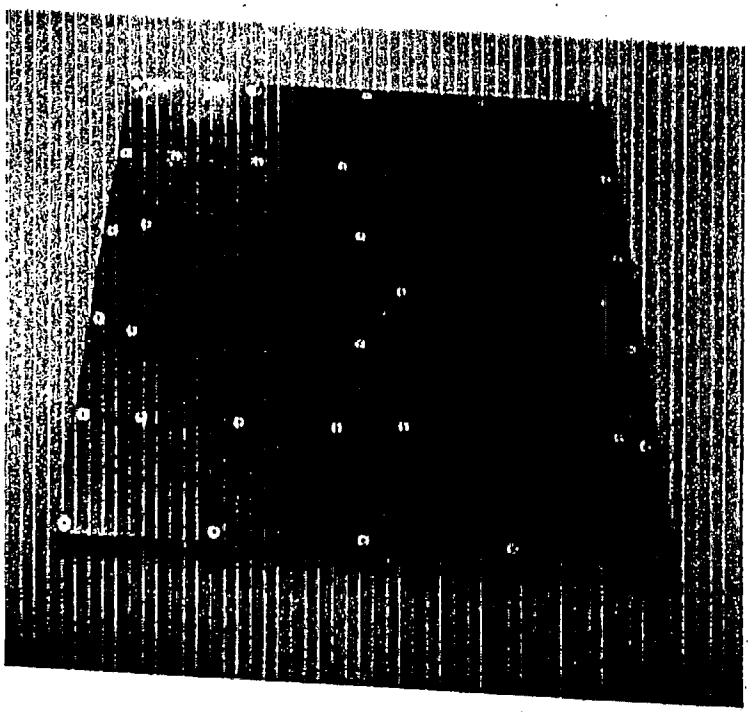
Carbon-Carbon Spacecraft Radiator Partnership (CSRP)

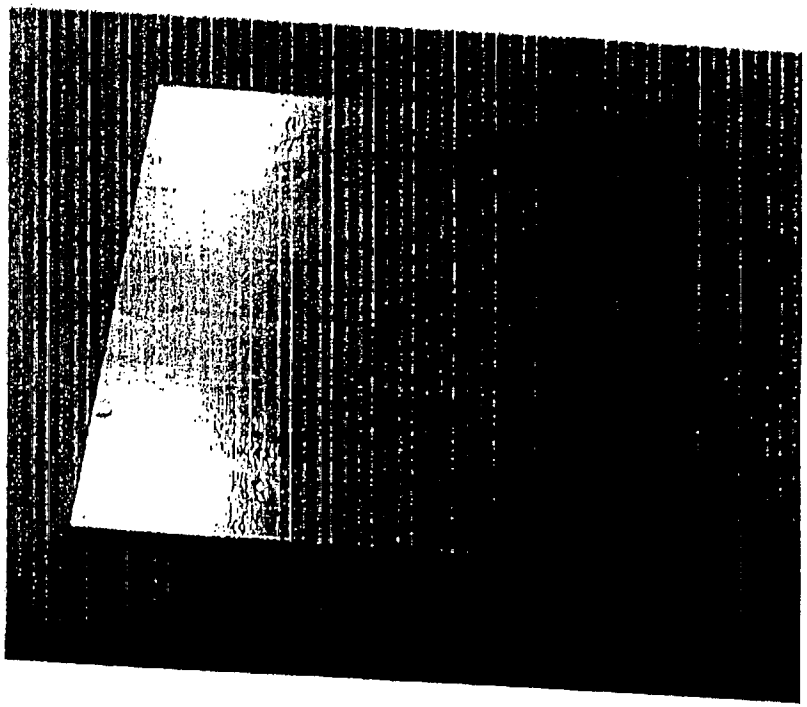
- CSRP started by Howard Maahs of NASA Langley and Elizabeth Shinn of Wright Patterson Air Force Base to promote the use of Carbon-Carbon as a radiator material
- CSRP was an informal partnership with members from government and industry
  - NASA Langley, NASA/Goddard, Air Force at Wright Patterson and Phillips Lab, Naval Surface Warfare Center,
  - TRW, Lockheed Martin, Amoco, B.F.Goodrich, Materials Research, Swales
- The New Millenium Program's EO-1 mission provided a flight opportunity for the CSRP
  - C-C radiator provided by CSRP at "no cost" to NMP

C-C Radiator on EO-1

- The C-C radiator replaces one of 6 structural panels on the EO-1 Spacecraft (S/C)
- Radiator consists of 1" Al honeycomb with 0.020" C-C face-sheets, approximately 28" by 28"
  - Utilizes 2 plies of P30X carbon fibers with carbon matrix established by Chemical Vapor Infiltration
  - Epoxy coated for strength and contamination protection
  - Aluminum inserts bonded to honeycomb core for mounting of electronics boxes and attachment to the S/C
  - Exterior coated with Silver Teflon for heat rejection
- CSRP delivered one flight unit and one spare to GSFC
  - Flight qualification testing completed at GSFC

EO-1 C-C RADIATOR





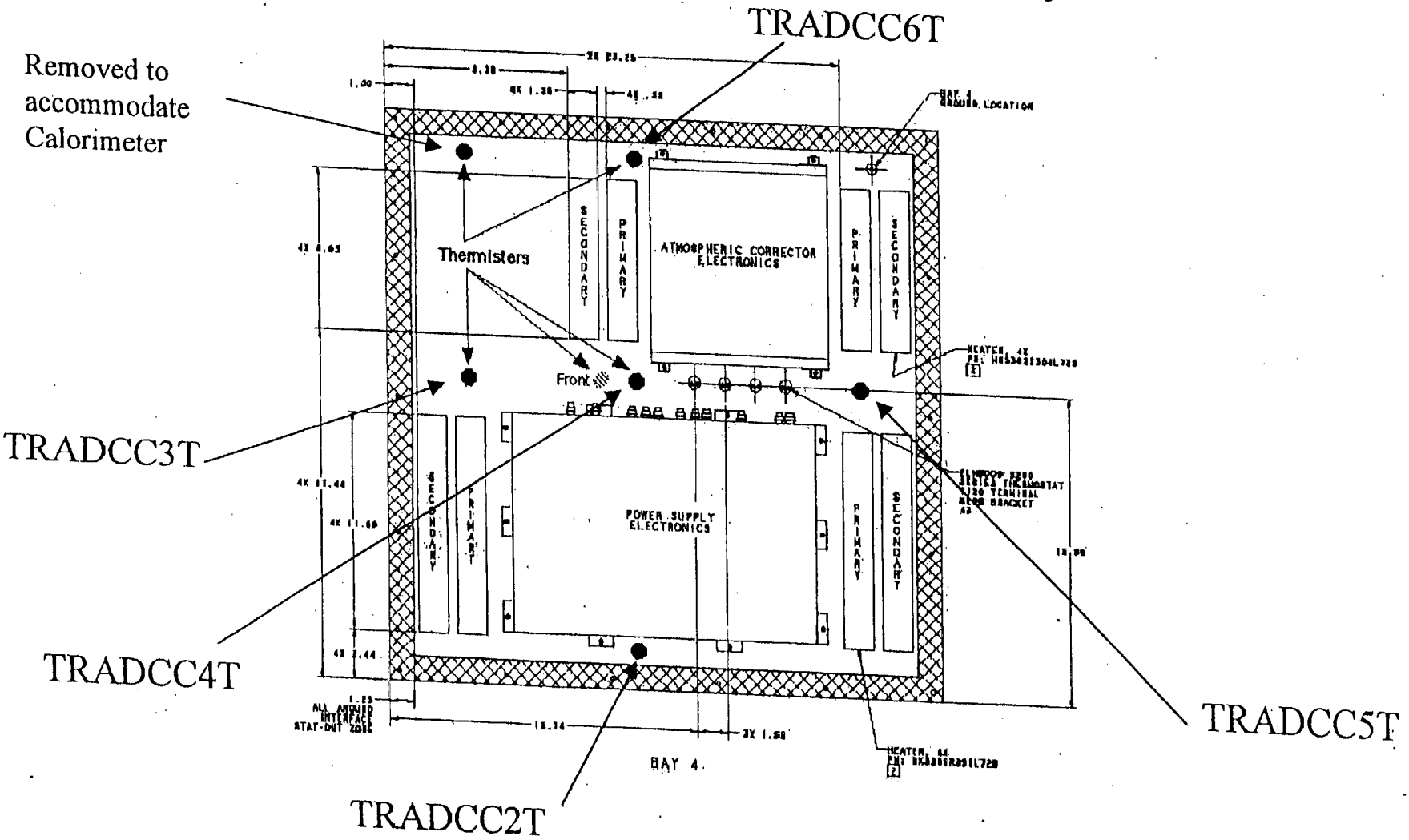
Carbon-Carbon Radiator Technology Validation

- Verify on-orbit thermal performance of C-C material meets S/C requirements, evaluate any degradation of thermal conductivity (none expected)
  - Thermal conductivity measured by testing (coupon level and Thermal Vacuum)
  - Thermal model correlated to test results and flight data
  - S/C level TV test provided additional verification, comparison for C-C flight thermistor readings
  - Monitor C-C thermistor data on-orbit, along with S/C attitude data.
  - Correlated flight data with C-C thermal model to verify proper C-C radiator performance

Validation Tasks Completed

- **Component Level Tests**
  - Thermal Vacuum/Thermal Balance,
    - Thermal Analysis and Model Correlation, Conductivity Verification
  - Vibration and Strength
    - Structural Analysis and Modeling
  - Mass Properties
  - Non-destructive examination (radiography) conducted before and after start qualification testing
- **Spacecraft Level Testing**
  - Vibration
  - Thermal Vacuum
  - EMI

CC Radiator Thermistor Layout



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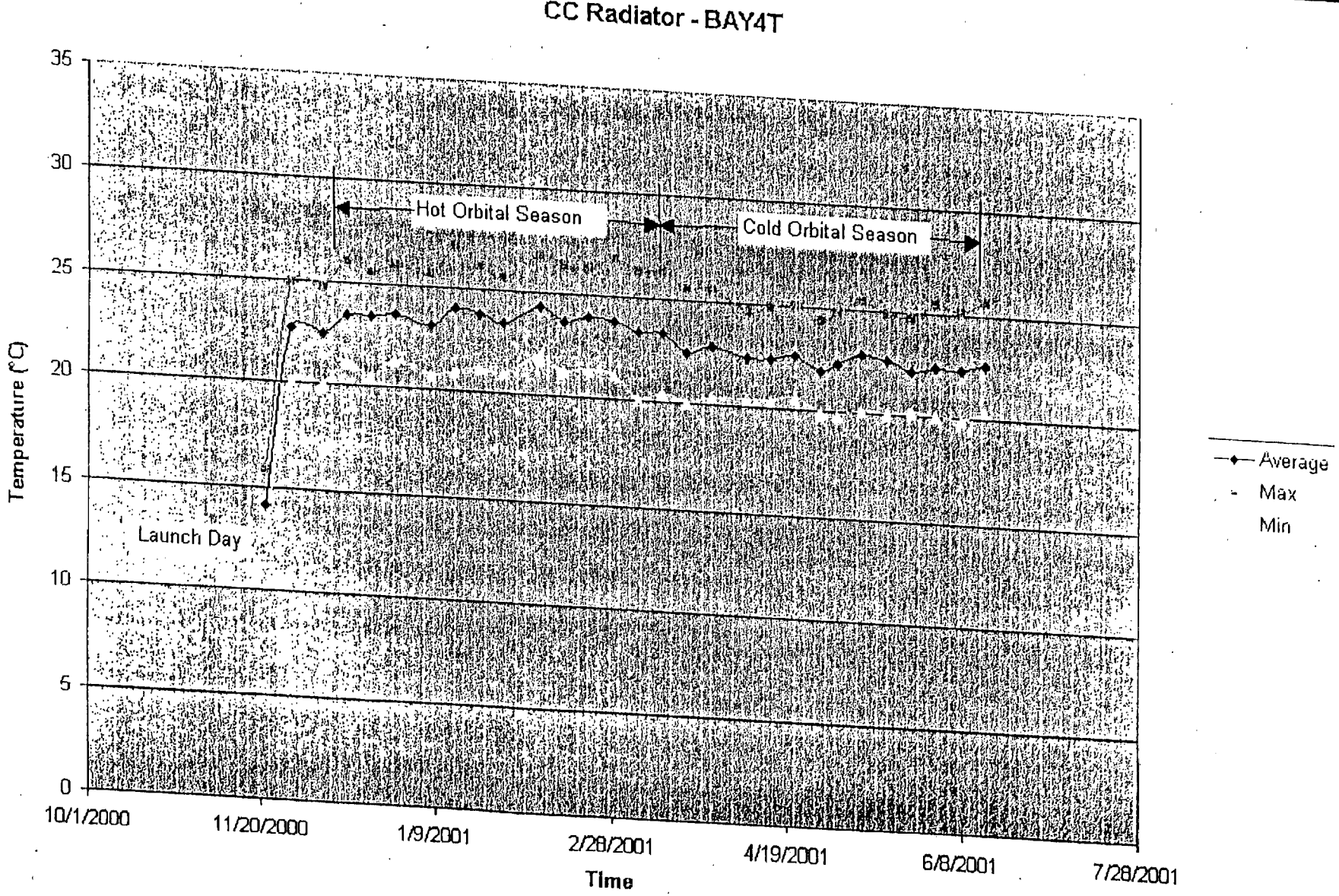
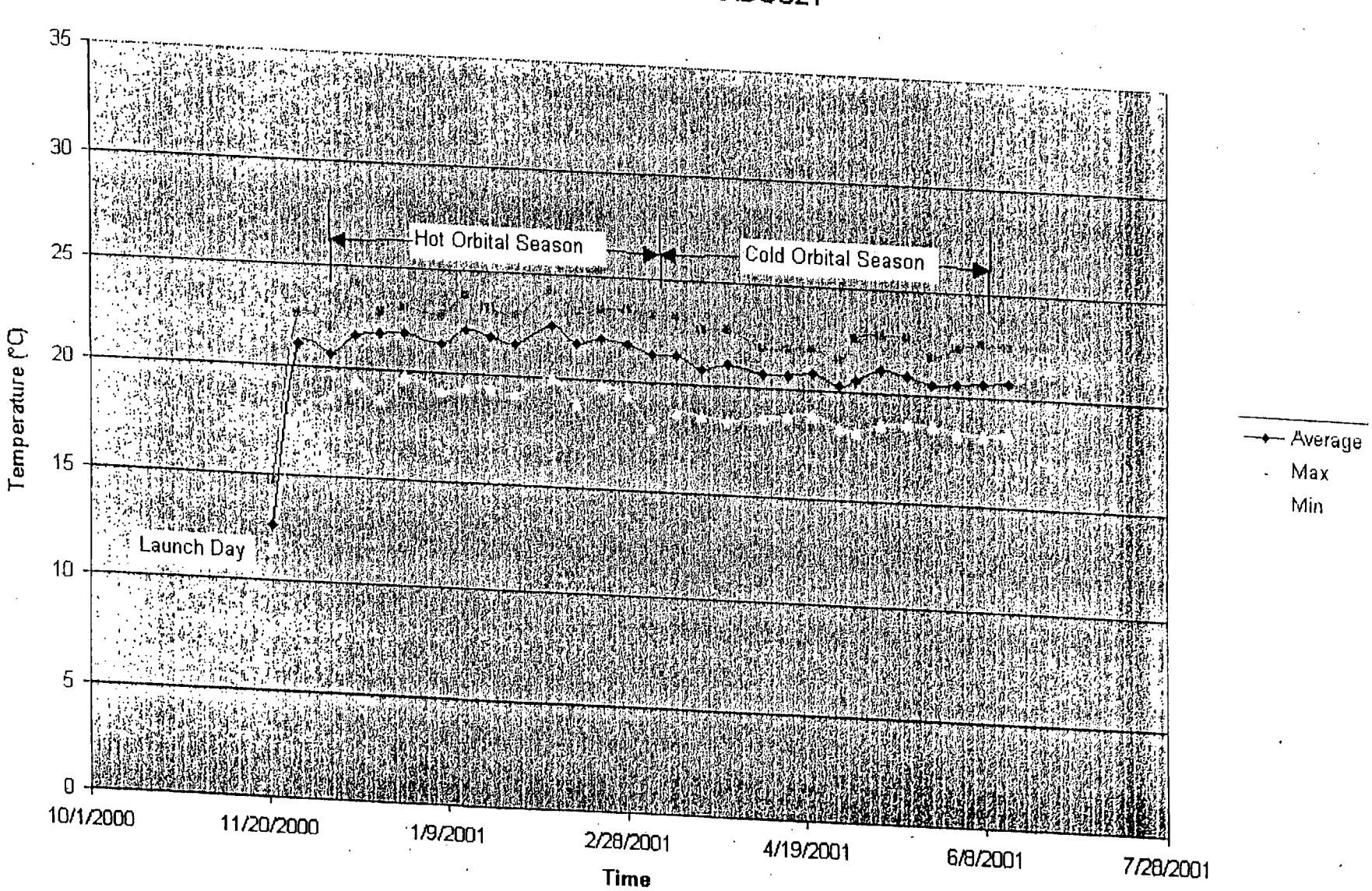
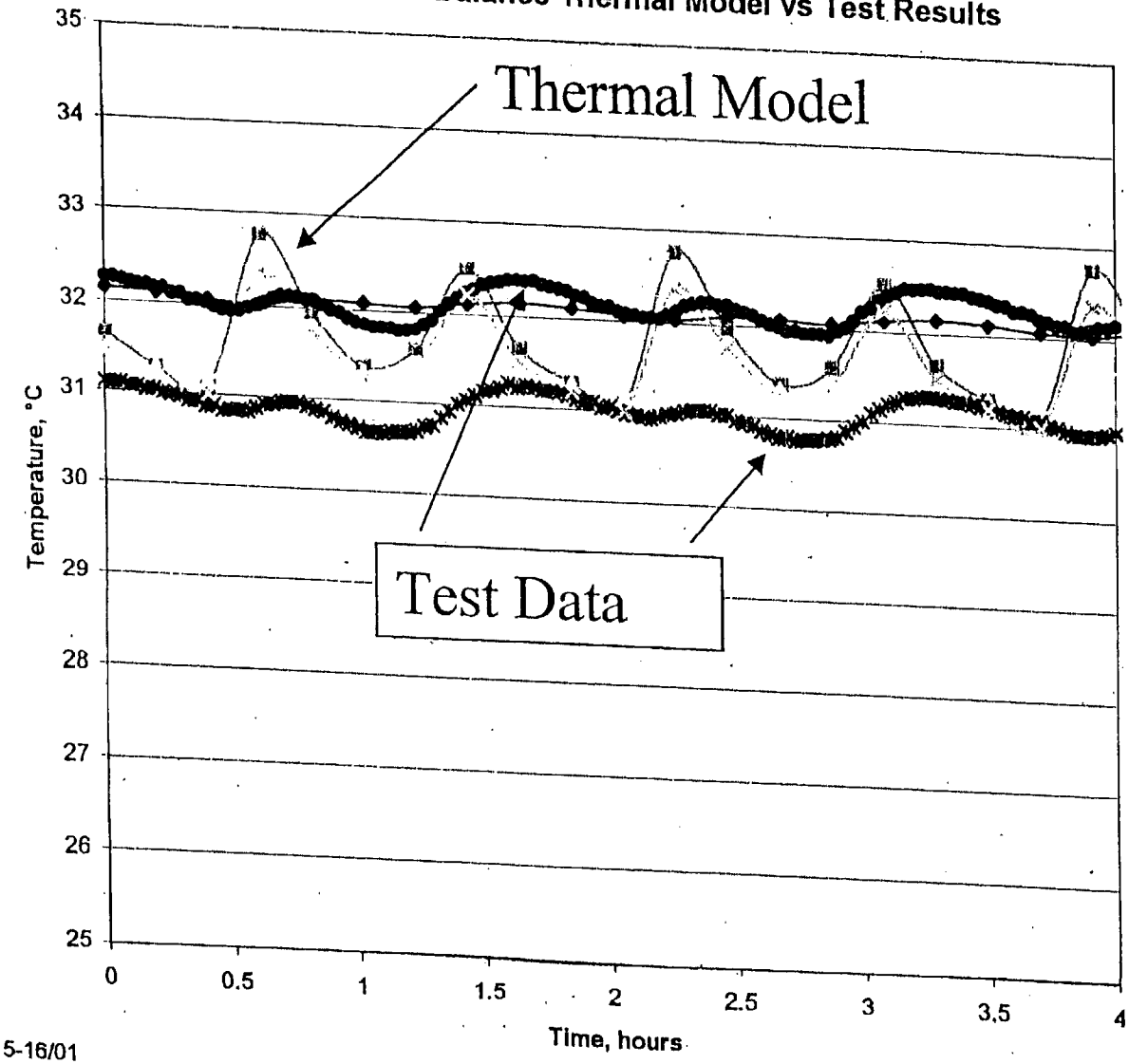
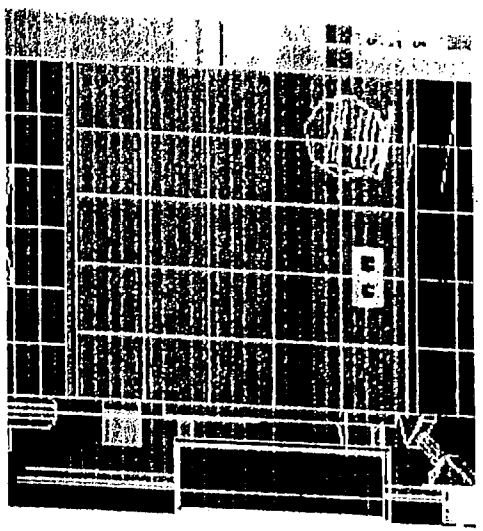

CC Radiator - BAY4T
Temperature (°C)
35
30
25
20
15
10
5
0
Hot Orbital Season
Cold Orbital Season
Launch Day
10/1/2000
11/20/2000
1/9/2001
2/28/2001
4/19/2001
6/8/2001
7/28/2001
Time
Average
Max
Min


CC Radiator - TRADCC2T
Temperature (°C)
35
30
25
20
15
10
5
0
Hot Orbital Season
Cold Orbital Season
Launch Day
10/1/2000
11/20/2000
1/9/2001
2/28/2001
4/19/2001
6/8/2001
7/28/2001
Time
Average
Max
Min

EO-1 HOT Balance Thermal Model vs Test Results



EO1.415 PSE Base Plate
EO1.420 LEISA Electronics
EO1.24162 Bay #4 Equipment Panel
Equip Pnl 4 ex cen TC-4
Radiator bay 4 TC-86
EO1.24163 Equipment Panel 4



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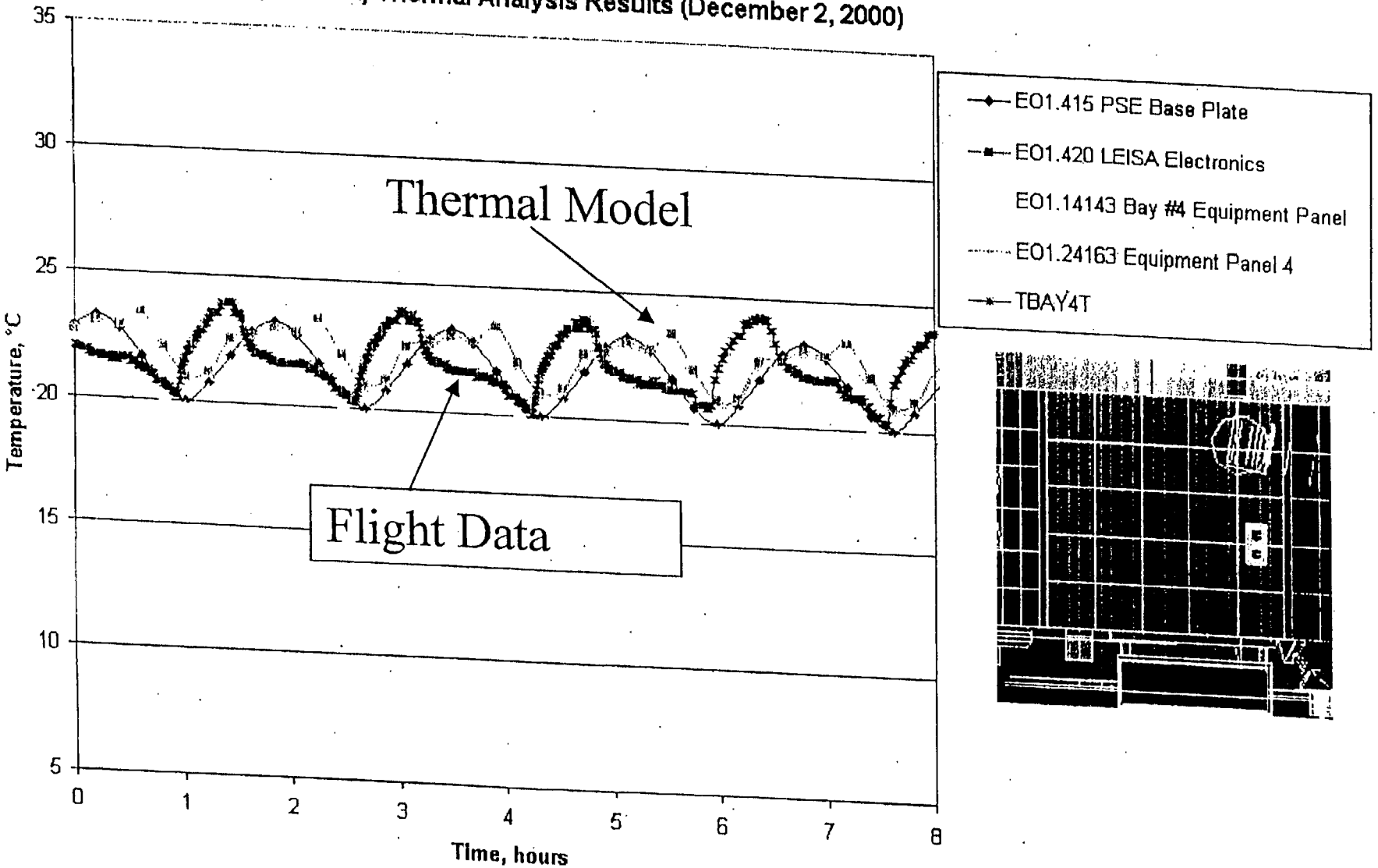
EO-1 DCE (Nominal) Thermal Analysis Results (December 2, 2000)



C-C Radiator Lessons Learned/Summary

- C-C Radiator was a success and proved that the technology can work to reduce Spacecraft weight
- C-C has a niche, especially for high temperatures
- C-C still needs further development (my opinion)
  - Reduction in fabrication time and cost - high conductivity "traditional" composites are more competitive
  - CTE Interface issues with heat pipes
- Redundancy a good idea - we flew the spare panel
- CSRP was a success - informal inter-agency partnership
  - Thanks to all who contributed - this was a fun job
- Possible follow-on : C-C foam for low CTE mirrors/optical benches
- Thanks to EO-1 project and Swales for this opportunity